EFFECT OF CEANOTHUS BRUSH ON WESTERN YELLOW PINE PLANTATIONS IN THE NORTHERN ROCKY MOUNTAINS [1]

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INTRODUCTION

Forest planting in the northern Rocky Mountain region is largely confined to areas that have been burned over twice, the second burning occurring during recent years. Planting crews can operate on these "double burns" with relative ease because the fires have removed shrubs and other obstructions. Unfortunately planting activity on forest lands is not keeping pace with the accumulation of areas denuded by fire, and as time passes these lands rapidly revert to shrubby growth from the uninjured roots of the original bushes and from wind-borne seeds. Released from competition, other than that of herbaceous plants, the bushes frequently usurp the area. This is especially true of *Ceanothus velutinus* on southerly slopes. Certain areas are considered "too brushy to plant" because of the mechanical hindrance of the bushes. On other areas those in charge of this work feel uncertain as to whether or not the beneficial effect of shade from the bushes is greater than the detrimental effect of root competition. Hence, when confronted with a bush in his path, the planter lacks instructions about the proper location of his seedlings. Each planter, therefore, follows the line of least resistance by avoiding the bushes as much as possible and setting his trees in the intervening spaces. A desire for definite information as a basis for improved practice led to the experiments reported here.

EARLY WORK WITH VARIOUS SPECIES

Observations made in other regions on the effect of various shrubs on conifer seedlings may be mentioned briefly. As early as 1912 Kimball and Carter (*6*),[2] working with white pine in Massachusetts, observed that medium or heavy low shade with root competition appeared preferable to no shade and no root competition. Later Hofman (*5*), working in the Cascade Mountain region, concluded that shade was not an important factor in reforestation except when the site is very poor or the shade very dense. Still more recently Show (*10*), working principally with western yellow pine in California, reached these conclusions:

1. Brush cover increases survival, and the benefit of shade is greater on poorer sites, for less drought-resistant species, and for poorer stock.
2. The quality of work done in planting improves as the brush cover decreases.
3. The influence of different species of brush is found to vary greatly. Manzanita is least detrimental to success in planting.
4. Increased shading results in increased height growth.

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[2] Reference is made by number (italic) to Literature Cited, p. 612.

From the early forest planting work in northern Idaho and western Montana it was evident that trees planted in the shelter of stumps and fallen logs usually survived better than those set in more exposed spots. The difference in moisture conditions seemed to be what affected the trees. These casual observations were verified by a special test in the spring of 1923 in which 800 trees were planted and half of them sheltered by shingles driven into the ground close to each plant on the sunny side. Two hundred western white pines (*Pinus monticola*) on a northwest slope and a similar number of western yellow pines (*P. ponderosa*) on a southwest slope were sheltered in this way. Survival of both species of trees was higher when sheltered than when in the open. It seemed natural to expect that the effect of brush on trees, so far as the tops only were concerned, should be similar to the effect of the logs, stumps, and shingles. That the adverse effect of root competition might more than offset the benefit of shelter was suggested by the results of another test made

FIGURE 1.—East slope bearing a scattered stand of *Ceanothus velutinus*. This was the site of the test plantation

that year (1923). Trees planted under bushes of various species and sizes did not do so well as similar ones planted in the open. No conclusions were possible, however, because of the small number of trees and the lack of adequate experimental control. These preliminary tests indicated the need for more intensive experiments.

EXPERIMENTS WITH YELLOW PINE AND CEANOTHUS

INSTALLATION OF TESTS

In the spring of 1926 a mountain slope, considered typical of much of the land in need of planting in the region (fig. 1), was selected for the experiment, near Haugan, Mont. It was a portion of the area burned in 1910 and constituted a uniform easterly slope bearing an evenly scattered stand of *Ceanothus velutinus*. The bushes consisted of numerous stems branching from the root collar, at which point the oldest stems were found to range from 10 to 14 years of age. However, most of the stems were found to be only about half as old and in their more or less sprawling position rose only from 2 to 4 feet from the ground. In this experiment it was desired to study the effect of brush on western yellow pine, independently of shade from other objects. Accordingly the area selected was one having a minimum number of dead trees either standing or down.

The trees for planting were taken from the general run of 1–2 western yellow pine stock at Savenac nursery after the most poorly developed specimens had been rejected, a number amounting to 13½ per cent of the total. Roots were pruned to a length of 8 inches. Six hundred bushes well distributed over the mountainside were selected, and three trees were planted (April 9–13, 1926) on the slope just below each bush. One tree was placed well under where it received much shade and root competition; one was placed well out where it received no root competition from bushes and very little, if any, shade; and the third tree was set in an intermediate position where it received some shade and doubtful root competition. This intermediate position was under the outer edge of the crown of each bush. All trees were planted by the same man in a uniform manner, using the method standardized for Forest Service planting in the region.

ENVIRONMENTAL FACTORS WORTHY OF STUDY

Apparently inconsistent results are often obtained from experiments with plants simply because of a dearth of information concerning some of the factors involved. However, the multiplicity of these factors and the impossibility of studying them all at any one time or place, necessitates the attempt to measure only a few and to control or eliminate the influence of others. In this experiment only the factors believed to be of most vital importance were studied. Years of experience indicate that of all environmental factors, moisture relations are the most influential on the life of planted trees. This was recognized by Korstian (*7*) working with western yellow pine in Utah. Although light was not studied in this experiment, because of the lack of suitable instruments and the belief that its rôle is subordinate to that of moisture, a study was made of the more readily measurable, and probably more significant, temperature relations.

When soil-moisture determinations can be expressed in terms of moisture available to the crop studied, their significance can be much more readily interpreted than when they are expressed in terms of total moisture. Accordingly, from several points scattered over the site of the test plantation, soil samples were taken to represent the upper 8-inch layer of soil. This earth was then used in the greenhouse for a determination of the wilting coefficient for western yellow pine. The method used was that advocated by Bates and Zon (*3*). The weighted averages employed in this method gave these results: Pan No. 1, 4.1 per cent; pan No. 2, 3.6 per cent; or an average, approximately, of 3.9 per cent, as the wilting coefficient. This figure was then applied to the results of field and laboratory determinations of total moisture, expressed in percentage of oven-dry weight, and shown in Table 1.

The death of plants from drought is due not only to the lack of available soil moisture but almost equally to the loss of moisture through transpiration of the tops. The external factor most directly

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affecting transpiration is evaporation, depending as it does on the combined influence of wind, temperature, and humidity, each of which is recognized as an important factor in the survival of plants during periods of drought. Accordingly, a study of evaporation was made involving the locations of the western yellow pines planted under Ceanothus. A typical bush was selected near the center of the plantation and two Bates evaporimeters were placed underneath, two in

FIGURE 2.—View of instruments as installed for a study of evaporation and temperature in relation to Ceanothus brush

the open space on the slope below, and one at the intermediate position under the edge of the crown. (Fig. 2.) A continuous record of evaporation at these three points was thus obtained for the 81 days from June 17 to September 6. Thus the figures given in Table 2 have a sufficient basis to show the average relative rates of evaporation under and away from the bushes during the summer period.

No thorough study was made of atmospheric humidity as an independent factor. Theoretically absolute humidity, because of transpiration from the foliage and evaporation from the moister soil, would be greater under the bushes than in the open. This condition, and also the lower air temperature in the shade, would cause a still greater contrast in relative humidity under the brush and outside. Such a contrast, if it actually exists over small areas, would naturally be greatest when the sun shines and no wind is blowing. Direct measurements of relative humidity with a cog psychrometer on two calm and sunny days gave the figures shown in Table 3. Undoubtedly average conditions, had they been determined, would show similar though less marked contrasts.

TABLE 1.—*Soil moisture in relation to Ceanothus*

[Moisture in percentage of oven-dry weight of soil]

Date	Position relative to brush	Basis (samples)	Total moisture	Wilting coefficient	Available moisture
1926		*Number*	*Per cent*	*Per cent*	*Per cent*
July 7	Open	7	6.2	3.9	2.3
Do	Intermediate	1	9.1	3.9	5.2
Do	Under	7	9.4	3.9	5.5
Aug. 7	Open	7	3.5	3.9	−.4
Do	Intermediate	1	3.2	3.9	−.7
Do	Under	7	4.5	3.9	.6

TABLE 2.—*Evaporation in relation to Ceanothus*

[Averages per 24-hour day]

Dates	Period	Position relative to bush		
		Under	Intermediate	Open
1926	*Days*	*Grams*	*Grams*	*Grams*
June 17–June 29	11.8	5	7	11
June 29–Aug. 3	35.0	6	10	15
Aug. 3–Sept. 6	34.2	4	6	7
June 17–Sept. 6	81.0	5	8	11

TABLE 3.—*Relative humidity in relation to Ceanothus (read from cog psychrometer)*

Date	Position relative to bush		
	Under	Intermediate	Open
1926	*Per cent*	*Per cent*	*Per cent*
July 2	62	48	47
July 6	44	40	33
Average	53	44	40

That soil temperatures are influential in plant life is generally recognized. The influence of forest cover on soil temperature has been studied recently by Li (*9*). He found that the forest cover near Keene, N. H., reduced the maxima, minima, and means of soil temperatures at all depths through the summer. This forest cover con sisted of a canopy of trees and the litter of the forest floor. Brush cover might reasonably be expected to have a similar, though less marked, effect. Records were obtained by the simultaneous operation of two carefully adjusted soil thermographs with soil bulbs extending from the surface to a depth of 8 inches, one under brush, the other in an adjacent opening. These thermograph traces form the basis for the graph shown in Figure 3. Apparently the brush had a marked effect in lowering soil temperature and reducing its range within the upper 8 inches where the planted roots are. Bates (*2*) emphasizes the importance of high temperatures at the surface of the soil, and Toumey (*11*) found that the surface temperatures varying from 122° to 131° F. killed very young, tender conifer seedlings. Although such high temperatures might not be actually fatal to the 3-year-old trees planted in these tests, it was thought that they might easily affect thrift and early growth. Thermometers observed during the period from June 17 to September 6 indicated the following maximum

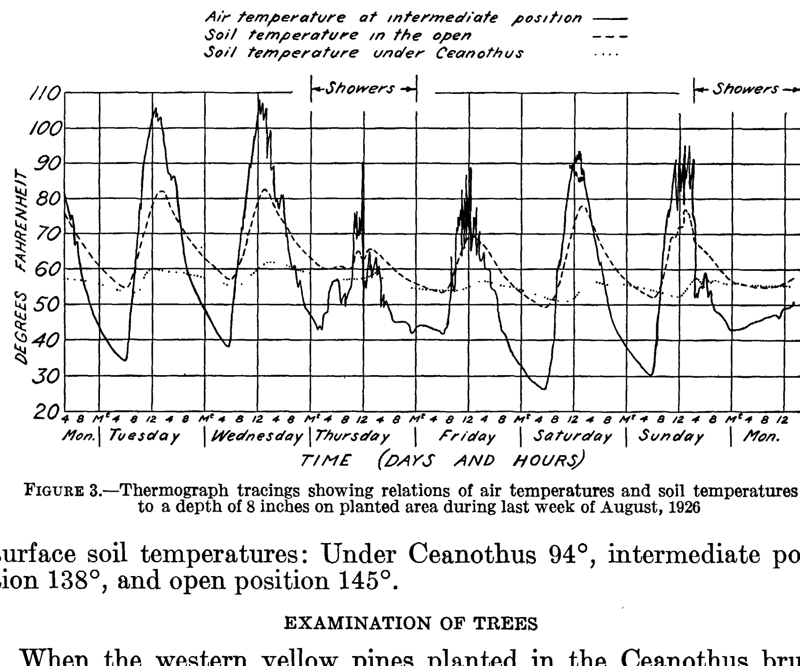

FIGURE 3.—Thermograph tracings showing relations of air temperatures and soil temperatures to a depth of 8 inches on planted area during last week of August, 1926

surface soil temperatures: Under Ceanothus 94°, intermediate position 138°, and open position 145°.

EXAMINATION OF TREES

When the western yellow pines planted in the Ceanothus brush field were examined in August, 1926, the foliage of the current year's growth on shaded trees was strikingly different from that on the unshaded ones. Under Ceanothus the needles on new shoots were longer, thinner, and more delicate in appearance than those grown in the open. The needles within each fascicle on shaded trees were well separated from each other in the normal way, whereas on trees standing in the open the new needles had not separated. These open-grown needles were very noticeably shorter and thicker than those grown in the shade, although not as thick as the long, mature western yellow pine needles from older trees. These differences in external appearance of shade-grown as compared with open-grown needles were so marked that it was thought worth while to look for corresponding differences in internal structure. Korstian (*8*), working with 3-year-old Douglas fir (*Pseudotsuga taxifolia*) seedlings in seed beds at the Cottonwood nursery in Utah, found that the leaves of shaded plants had a less compact structure, thinner epidermis and cuticle, more spongy tissue, closer lying cells, and less deeply depressed stomata than plants growing in the open sunlight. Laboratory study of the yellow pine needles failed to reveal any such significant differences in cell structure, but it served to illustrate more clearly the relative size of the needles as a whole. Figure 4 shows that the shade-grown needles, although apparently healthy and normal in

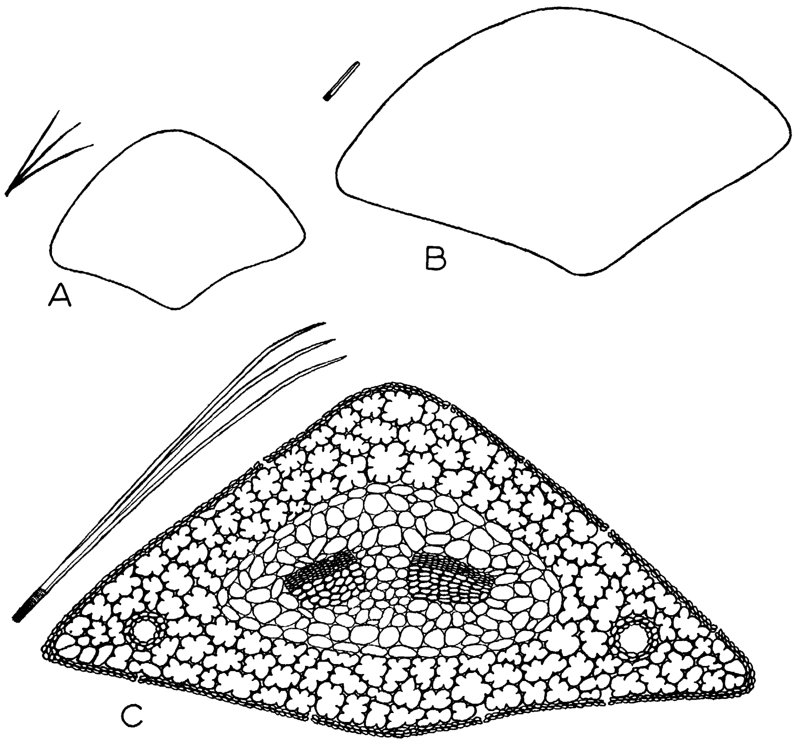

FIGURE 4.—The diagram shows the relative size of needle fascicles (one-half actual size) and cross sections of needles (magnified seventy-five times) from 3-year-old western yellow pine transplants planted (A) under a Ceanothus bush and (B) in the open. The figure also shows (C) fascicles and cross section of a 13-year-old, naturally seeded, open-grown, western yellow pine from the same area. The internal structure of A and B is similar to that shown for C

structure, were much more slender and delicate than the needles from an older open-grown and naturally seeded yellow pine. The needles from the tree planted in the open were intermediate in thickness and doubtless would also have been intermediate in length had it not been for the action of drought. Obviously drought caused a cessation of development in these new needles, leaving them short and closely appressed in the fascicle, as shown in the drawing. This did not happen to the new pine needles under the Ceanothus because of the greater soil moisture and less desiccating atmospheric conditions existing there, as indicated by the above tables.

It was evident that under the bushes evaporation was less, and that, at least during periods of little wind and much sunshine, humidity was higher than in the open. Furthermore, as indicated in Table 1, by the end of the first week in August the moisture available to western yellow pines planted in the open had been completely exhausted, whereas a little available moisture still remained under the bushes. This observation led directly to an examination of each of the 1,800 trees in the plantation, since, theoretically at least, the trees in the open should be found dying in large numbers as a result of the more intense drought in the open spaces. The actual condition of the plantation at that time is shown in Table 4.

TABLE 4.—*Average condition on August 20 of western yellow pines*[a] *planted April 9–13, 1926, among Ceanothus bushes on an east slope in western Montana*

Condition	Open position	Intermediate	Under Ceanothus
	Per cent	*Per cent*	*Per cent*
Thrifty	40	57	80
Unthrifty	13	11	9
Alive	53	68	89
Dead	47	32	11

[a] Basis, 600 trees in each of the three positions.

This table indicates clearly that the trees planted closely under the brush survived best during the dry season following spring planting. It seemed that the problem was already more than half solved because the first dry season is always the most critical time in the life of the planted trees. The possibly keener competition in the future between the more deeply penetrating roots of the trees and shrubs is not especially to be feared, because the shock associated with planting will have been outgrown and the tops of the bushes will still provide beneficial shelter from extreme atmospheric conditions. So far as the attainment of high survival is concerned, it seems safe to recommend that yellow pines be planted as close to Ceanothus bushes as is practicable without appreciably lowering the quality of planting.

However, this early high survival under brush will be useless if the bushes ultimately "smother out" the trees. It is not always true that those environmental conditions which favor plant life in general favor both survival and growth. Sometimes the same conditions that favor survival retard growth and vice versa. Such an observation was made on western white pine in an earlier study (*12*), in which trees planted on a steep northwest slope survived best of all the lots tested but grew least rapidly, while the trees on the severe west slope survived least well, but grew most rapidly during the first three years following planting. Similarly in the present study it may be found that the conditions that favored high survival under the bushes may be such as to retard growth of the trees. However, it does not seem likely that Ceanothus can permanently suppress these yellow pines when one considers the prevalence of brush fields following destructive fires and the widely accepted idea that all stands of timber represent a more advanced stage in plant succession in timber regions than do the shrub types. Proof of the natural dominance of the trees or brush in this experiment can be finally obtained only by observation of the trees year after year until they have either died or grown out above the bushes. In the meantime it seemed desirable to gather empirically some evidence of the probable result of this association of brush and trees. About a week was spent in scouting through various brush areas to observe whether or not naturally seeded trees were successful when they happened to start life close to various bushes, especially Ceanothus. A special hunt was made for trees that had emerged above the brush or died in the attempt. In several cases, where yellow pines were found emerging above dense brush, the trees were found to stand but a few inches from the root collars of older bushes, a condition indicating that the bushes had a start in the race with trees that grew well within the soil areas the bushes utilized. Although many instances were found of trees successfully emerging after apparently keen competition, it seems significant that only one failure was discovered. No statistical summary of these observation can be presented, but Figures 5 to 8 illustrate special cases which have a bearing on the subject.

Such observations appear to indicate that brushes hinder growth of tree seedlings only temporarily, if at all, and that such hindrance will increase the rotation period in timber growing by a negligible amount.

Ceanothus is one of the few nonleguminous plants that is suspected of harboring bacteria that add nitrogen to the soil in available form. Arzberger (*1*) and Bottomley (*4*) report finding root nodules on this genus and the writer has observed them on the roots of the local species. That nitrogen in a form available for the use of plants is lost from the soil as a result of forest fires is often overlooked. Yet available nitrogen is one of the elements of soil fertility that most profoundly affects the growth of trees. If stands of Ceanothus fix nitrogen in the soil in appreciable amounts on burned areas, they may increase the rate of tree growth for many years after their protection against loss of trees from drought is no longer needed. Except in fully and evenly stocked young stands of pine, Ceanothus bushes frequently live among the trees during their sapling and pole stages or longer, and as long as the shrubs do so persist they may be stimulating the growth of the timber, and thus Ceanothus may be an asset even beyond its early beneficial effect in forest regeneration.

SUMMARY

During dry summer weather in western Montana it was found that under Ceanothus brush atmospheric evaporation was less, relative humidity greater, soil temperature lower, and soil moisture greater in amount than in adjacent open spaces. As a result of such conditions it was also found that survival of western yellow pines during their first dry season following field planting was much higher under the bushes than in the open. Although future records of growth are needed to show definitely whether or not the trees under the brush can successfully emerge, observations of natural reproduction indicate that brush can not permanently suppress tree growth.

FIGURE 5.—The seedling in front of the white paper is 6 years old, 14 inches high, and stands 7 inches from the root collar of an 11-year-old bush. Although the dense Ceanothus brush is 2 to 3 feet high and completely covers the seedling, the tree grew 3¼ inches during its last year (1926). Its thrifty condition indicates that it has a good chance to emerge eventually

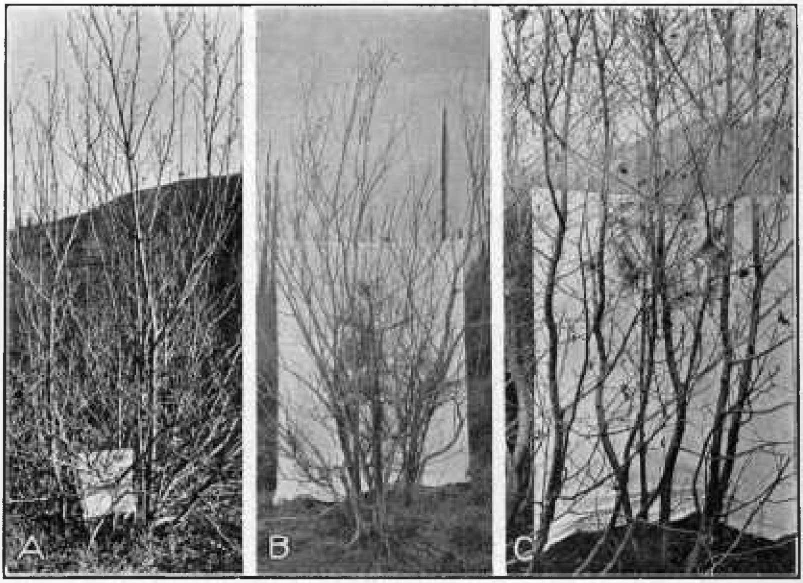

FIGURE 6.—A, The western yellow pine seedling, in front of the white paper, is 5 years old and 14 inches tall. The service-berry bush is 8 years old and 11 feet 5 inches tall. Both are in thrifty condition; B, this yellow pine is 8 years old and 4 feet 7 inches tall, and the willow bush is 11 years old and 8 feet 7 inches tall. In spite of the fact that the pine stands in actual contact with the root collar of an older and thrifty bush, the tree grew about 8 inches during each of the last 4 years; C, this western pine is 10 years old, 5 feet 9 inches tall. It stands in contact with the root collar of a 10-year-old alder bush that is 14 feet 4 inches tall. Although the tree is slender, as a result of the dense shade, it is healthy and growing

FIGURE 7.—The western yellow pine in the center sprang from seed and is now emerging above dense Ceanothus brush. The 11-year-old tree stands 13 inches from the root collar of a 13-year-old bush

FIGURE 8.—The center pine in this picture sprang from seed 13 years ago. It is now well above the 14-year-old Ceanothus bushes that crowd it from all sides. The root collar of the nearest bush is 7 inches from the base of the tree

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